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Application of ERTS-1 Imagery to Detecting and Mapping Modern Erosion Features, and to Monitoring Erosional Changes, in Southern Arizona[1]

SR 182

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Type I Progress Report

ERTS-1

a. Title: Application of ERTS-1 imagery to detecting and mapping modern erosion features, and to monitoring erosional changes, in southern Arizona. ERTS-A proposal No. SR 182.

b. GSFC ID No. of P.I.: IN 050

c. Problems encountered:

Delay in receiving enlargements of the ERTS images has hampered efficient mapping of data interpreted from the images. Positive transparencies at 1:1 million scale, ordered in mid-January from GSFC were received about 6 weeks later, but those ordered at the same time from Sioux Falls Data Center were not received until early April; enlarged prints at 1:250,000 scale, also ordered in mid-January from Sioux Falls DC, were received in mid-April. Both groups of transparencies are of good photographic quality. Those from Sioux Falls DC generally seem to be slightly superior for our purposes, except for some small scratches, and being slightly smaller scale than the GSFC enlarged transparencies.

d. Accomplishments during the reporting period:

Image-evaluation forms

A product of the indexing and preliminary evaluation of all ERTS-1 70-mm images received for this project is a series of image evaluation forms. These give an evaluation of each image that covers all or part of each 1°x2° quadrangle within the project study area, in terms of (1) its coverage of a specific quadrangle, (2) cloud cover, (3) contrast, (4) resolution, (5) atmospheric degradation, and (6) other defects. These forms are reproduced as Appendix A of this report.

Phase 1 results *

Phase-1 mapping (using only ERTS-1 imagery, without input of additional data) is nearly completed. The Type II progress report for the period 15 July 1972 to 31 January 1973 included a map showing the modern arroyos in the 18,000-square-mile study area that are detectable from ERTS-1 imagery. Images received subsequent to January 1973 do not justify significant additions to this phase-1 map.

We attempted to identify the areas of modern sheet erosion and concluded that such areas cannot be identified and differentiated accurately at the phase-1 level of mapping. However, the areas that are most liable to sheet erosion (those of the readily erodible soils) can be differentiated with considerable accuracy, as will be explained in the next paragraph.

* Appendix B describes the seven-phase interpretation program followed in this project.

Mapping of "readily erodible soils," gravelly alluvium, and bedrock -- Essential to any study of erosion is classifying and mapping the materials exposed at the land surface. As a final part of the phase-1 mapping (still in progress), we are using ERTS-1 imagery to prepare a map of the entire study area giving a threefold division of materials: those that are least prone to erosion (the consolidated rocks -- "bedrock"); those that are most prone to erosion (here called the "readily erodible soils," mainly fine-textured unconsolidated alluvium); and an intermediate unit (gravelly alluvium).

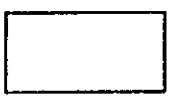
Figure 1 is an example of this type of map. It was prepared as an overlay to 1:1 million black-and-white enlarged positive transparencies of MSS bands 5, 6, and 7 of ERTS-1 frame 1085-17330 (16 October 1972), which includes the Phoenix and part of the Tucson metropolitan areas. Commonly the "red" band 5 gives the best contrast between the three units mapped, although in some areas the infrared bands 6 and 7 are equally satisfactory or provide somewhat better tonal differentiation. The 1:1 million black-and-white transparencies were viewed under 4x to 10x magnification on a light table. Adjunct viewing of 70-mm positive transparencies of the same frame under a binocular microscope (with 9x magnification) gave slight improvement in detectability and tonal differentiation. Considerable improvement in detectability differentiation was obtained by stereoscopic viewing (using an Old Delft scanning stereoscope with 4.5x magnification) of the portions of this frame that overlap with adjacent frames at each side. (About 37% of the central part of this frame could not be viewed stereoscopically.)

Critical for the objectives of this project is mapping of the "readily erodible soils." These are predominantly alluvial soils of late Quaternary age that are unconsolidated or only slightly consolidated and fine textured (sand, silt, and clay). They occur chiefly in the interiors of the larger intermontane basins, beyond the zones of gravel deposition near the mountains. Here they are present not only on the flood plains and lower terraces of the principal streams, but commonly also on the lower parts of the piedmont alluvial plains (bajada toe slopes) where the flood plains of the desert washes spread out and coalesce. Thus, the interior lowlands of the larger intermontane basins have extensive areas of readily erodible soils, commonly miles wide. (In places in the interior lowlands, however, older soils are present that resist erosion because of hardpan development -- concentration of calcium carbonate, commonly called caliche, in the subsoil.) Readily erodible soils also occur locally on stream flood plains in some mountain, hill, and gravel piedmont areas.

The most conspicuous areas of readily erodible soils on this ERTS frame are those of young alluvial silts and sands on the bajada toe slopes. These are much lighter toned than the gravel piedmont and bedrock areas, owing to their high reflectance and to the scantiness of their vegetative cover. Some areas of these soils, especially the flood plains of the larger streams, appear dark-toned or varitoned because of natural and artificial vegetation -- cropland, grassland, and riparian thickets/groves of mesquite and other trees and shrubs, in various mixtures.

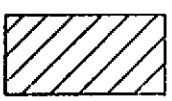
Figure 1. Preliminary (phase-1) soil-erodibility map from ERTS-1 frame 1085-17330 (mainly band 5).

Explanation



Readily erodible soils. Unconsolidated to weakly consolidated fine-textured alluvium of late Quaternary age. (Mapped only within project study area.)

Difficultly erodible gravelly soils. Unconsolidated to moderately consolidated and locally cemented gravelly alluvium of late Cenozoic age. (Mapped only within project study area.)



Consolidated rocks. (Mapped throughout the ERTS frame.)

———?— Contact (dashed where gradational or approximate, queried where problematic).

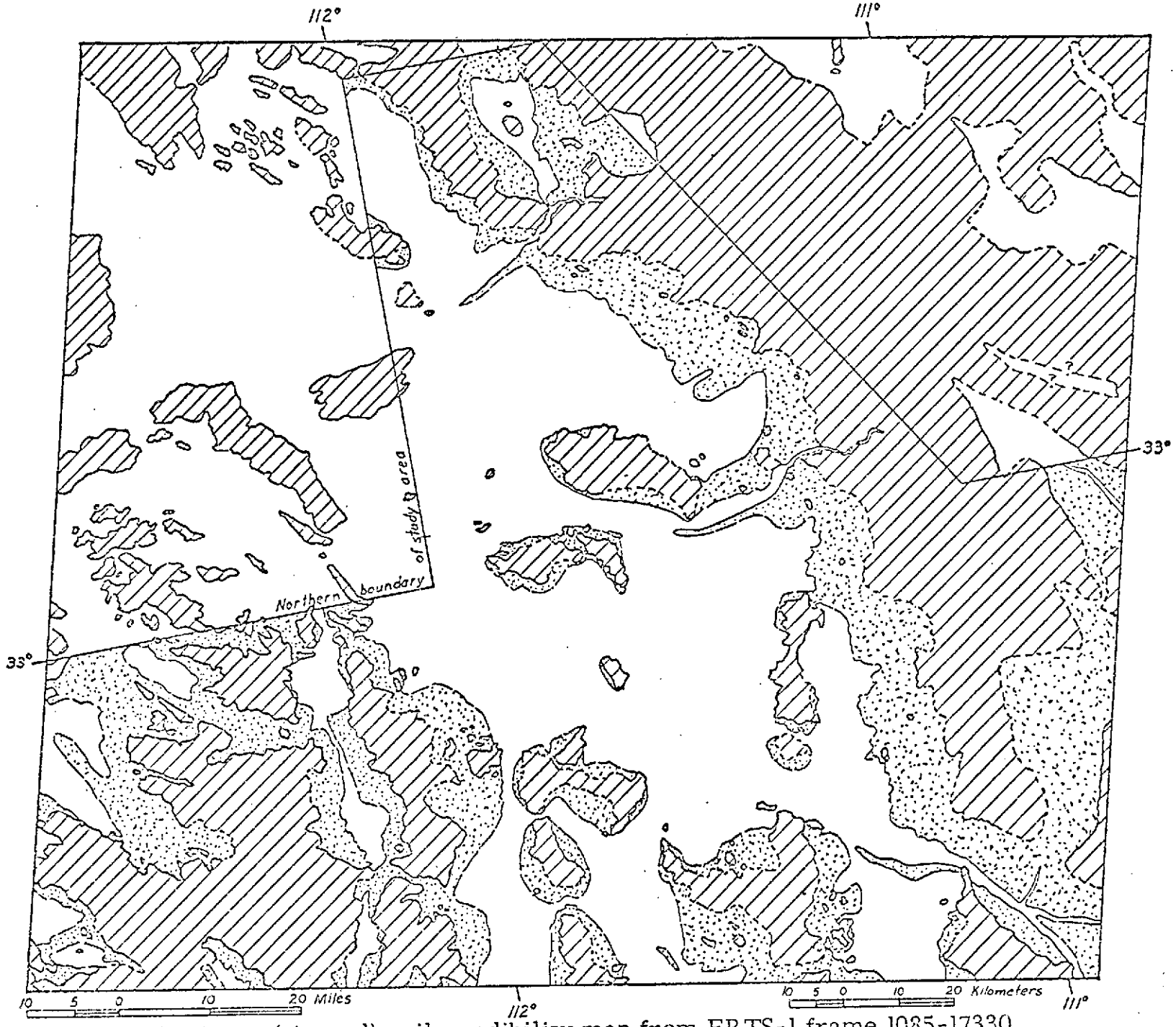


Figure 1. Preliminary (phase-1) soil-erodibility map from ERTS-1 frame 1085-17330

Figure 1 also shows the boundary between consolidated rocks (bedrock) and alluvial deposits, as interpretated from the ERTS image. A check on the accuracy of the photointerpretive mapping of this contact is provided by figure 2, for which the contact was taken from the 1:1 million-scale geologic map of Arizona, published by the Arizona Geological Society in 1967. Figures 1 and 2 generally are in good agreement as to the bedrock-alluvium boundary in the central and southwestern parts of the frame, where the contrast between bedrock and alluvium generally is high. However, this boundary cannot be differentiated accurately in certain areas of extensive pediments on light-toned rocks such as granite. Major discrepancies are evident in the mountainous northeastern part of the frame. Here the alluviated intermontane valleys are relatively narrow and moderately to highly dissected, and commonly the dissection and tonal patterns of the alluvium and adjacent bedrock areas are similar. Testimony as to the obscurity of the bedrock-alluvium boundary in these areas is given by the northeastern part of figure 1, where most of the alluviated valleys are shown much narrower than they really are. Valleys less than about 7 miles long and 3 miles wide could not be identified with certainty from the ERTS image alone. However, the outlines of such valleys can be identified vaguely if the interpreter superposes the 1:1 million-scale image on the geologic map of the same scale.

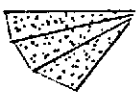
A distinct advantage of a geologic map produced from the ERTS 1:1 million-scale images is that it will have greater planimetric accuracy than the existing 1:1 million-scale geologic map, which was plotted on an old non-photogrammetric base map of Arizona.

Figure 2 shows an additional feature that can be mapped from the ERTS imagery -- alluvial fans. These show dramatically; many of them were identified for the first time as a result of the large overview provided by the ERTS image. A twofold differentiation can be made, into the dissected fans of late Cenozoic (Pliocene and younger) age and the relatively undissected fans of late Quaternary age. The latter are mantled by some of the most readily erodible soils in southern Arizona.

Detailed mapping of selected key areas.--In selected parts of the study area the modern erosion phenomena and features pertinent to the erosion problem are being mapped in detail, primarily by interpretation of ultrahigh (U-2 and RB-57) airphotos. This is to provide a basis for evaluating the mapping done from the ERTS images (both the normal images and those enhanced by special processing of the digital tapes by the Jet Propulsion Laboratory). During the reporting period we evaluated various areas as potential sites for the detailed mapping, and we selected eight key areas, established priorities for their mapping, decided upon the units to be mapped and the mapping procedure, and began mapping two of the areas. The eight key areas represent all the major environments pertinent to the erosion problem in terms of geology, soils, climate, topography, and vegetation. In these areas we are mapping not only the modern (post-1890) erosion (and deposition) phenomena (arroyos, gullies, modern flood plains and terraces, and areas of sheet erosion and deposition), but also other relevant features: classes of slope and local relief, landforms, rock units, soil particle size and erodibility, and vegetative cover.

Figure 2. Alluvial fans identifiable on ERTS-1 frame 1085-17330, band 5.

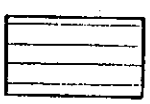
Explanation



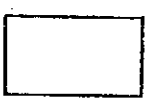
Relatively undissected alluvial fans of late Quaternary age

Dissected alluvial fans consisting of alluvium of late Cenozoic age

XXX Small coalescing alluvial fans whose outlines are indistinct on the ERTS image



Areas of exposed consolidated rocks, mainly mountainous and hilly areas. Boundaries are from 1:1 million-scale Arizona Highway Geologic Map (Cooley, M. E., and others, 1967, published by Arizona Geological Society).



Valley areas underlain by alluvium of late Cenozoic age.

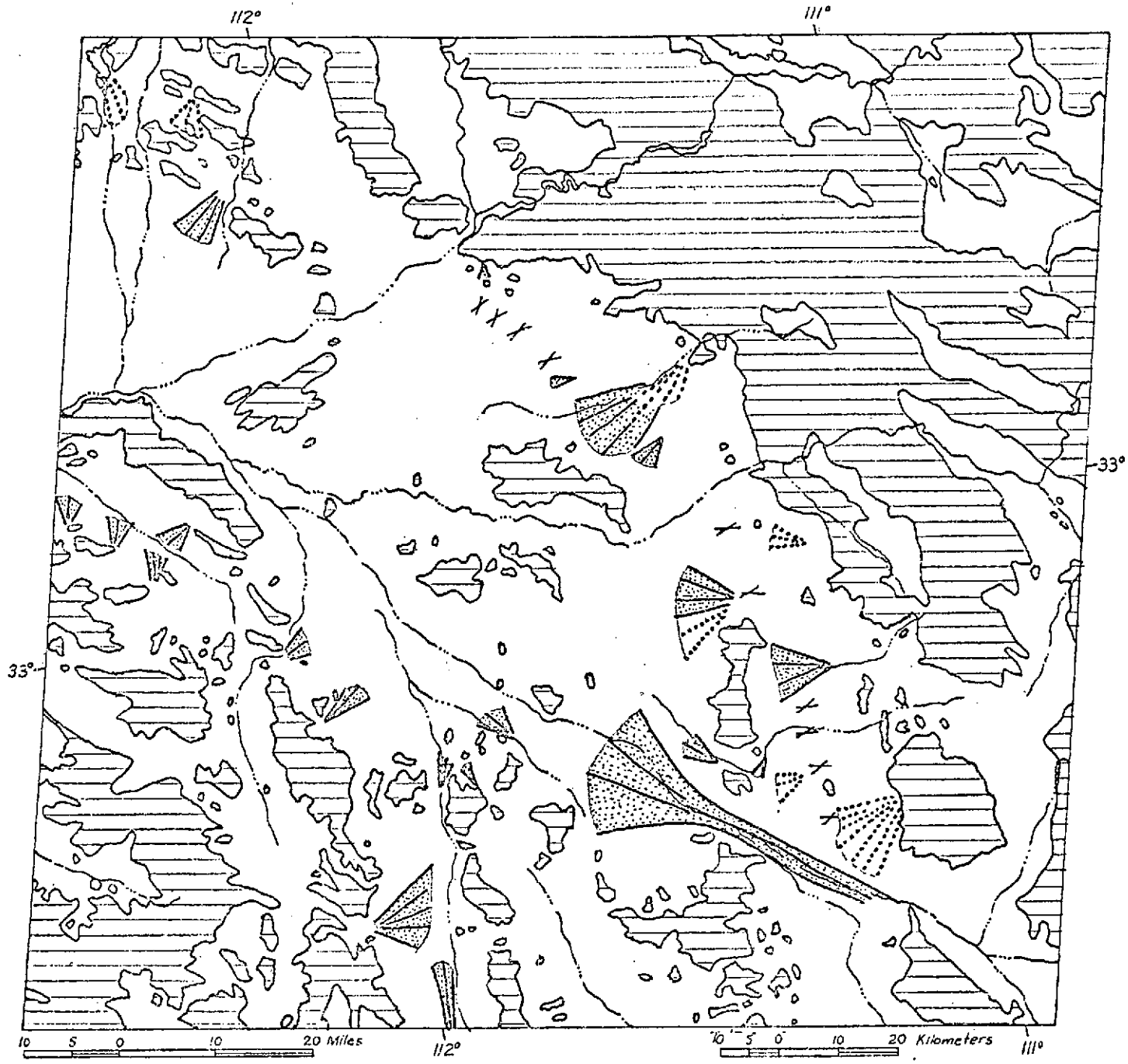


Figure 2. Alluvial fans identifiable on ERTS-1 frame 1085-17330, band 5.

Field studies were commenced in the key areas near Tucson and Mesa. We established the units and features that will be mapped (such as the classes of gullies, degrees of sheet erosion, soil-erodibility classes, and vegetative cover classes). Heights of stream terraces of Holocene age, including those formed since 1890, were measured at different points along the San Pedro and Santa Cruz Rivers, Cienage and Sonoita Creeks, and Railroad Wash. Some of the measurements, particularly on Sonoita Creek and Santa Cruz River, were taken at places measured 6 to 10 years ago. In addition, several profiles were measured across the modern arroyo of Railroad Wash.

ERTS-1 images as an aid in mapping linear structural features in Arizona--The Arizona Geological Society has requested Mr. Cooley to compile a new tectonic map of Arizona, utilizing published and unpublished geologic data, ERTS-1 images, and high-altitude airphotos. The general procedure to be followed is outlined in Appendix C. Cooley has worked on this compilation on his spare time, at no cost to the present project. He has found that the ERTS images obtained for this project help considerably in identifying linear structural features. In numbers of cases, extensions of known faults were found, as well as a myriad of possible faults. Figure 3 shows the phase-1 mapping of linear structural features identified on the same ERTS frame used for figures 1 and 2.

Interpretation of ultrahigh airphotos for preparation of flood-hazard maps

In addition, we acquainted personnel of the Arizona District, Water Resources Division, U.S. Geological Survey, with the NASA ultrahigh (U-2 and RB-57) airphotos of the project area, and aided these people in interpreting the airphotos for preparation of detailed maps of flood-prone and flood-hazard areas.

Plans for next reporting period

1) Complete the phase-1 map from the ERTS-1 images, showing the distribution of readily erodible soils, gravel piedmonts, and consolidated rocks, for the entire study area at 1:1 million scale.

2) Continue phase-2 mapping (detailed photointerpretative mapping of the selected key areas within the general study area, using the ultrahigh airphotos); also make appropriate field studies to obtain necessary supplementary ground truth.

3) Continue preparation of a phase-4 map ("enhanced information map"), utilizing both ERTS images and ultrahigh airphotos as well as available published and unpublished ground truth data, of the entire study area, at 1:500,000 or larger scale.

e. Significant results and their practical applications:

The chief results during the reporting period were three 1:1 million-scale maps made from one ERTS-1 frame (1085-17330, 16 October 1972) showing: (1) the three most important types of materials in terms of the modern erosion problem: the readily erodible soils, gravel piedmonts and basin-fill areas, and consolidated rocks; (2) alluvial fans (dissected and relatively undissected); and (3) (as an additional bonus) linear structural features. Eight key areas (small parts of the whole study area) were selected for detailed study, and mapping was started in two of them, by interpretation of ultrahigh (U-2 and RB-57) airphotos, supplemented by field studies. In these areas we mapped in detail not only

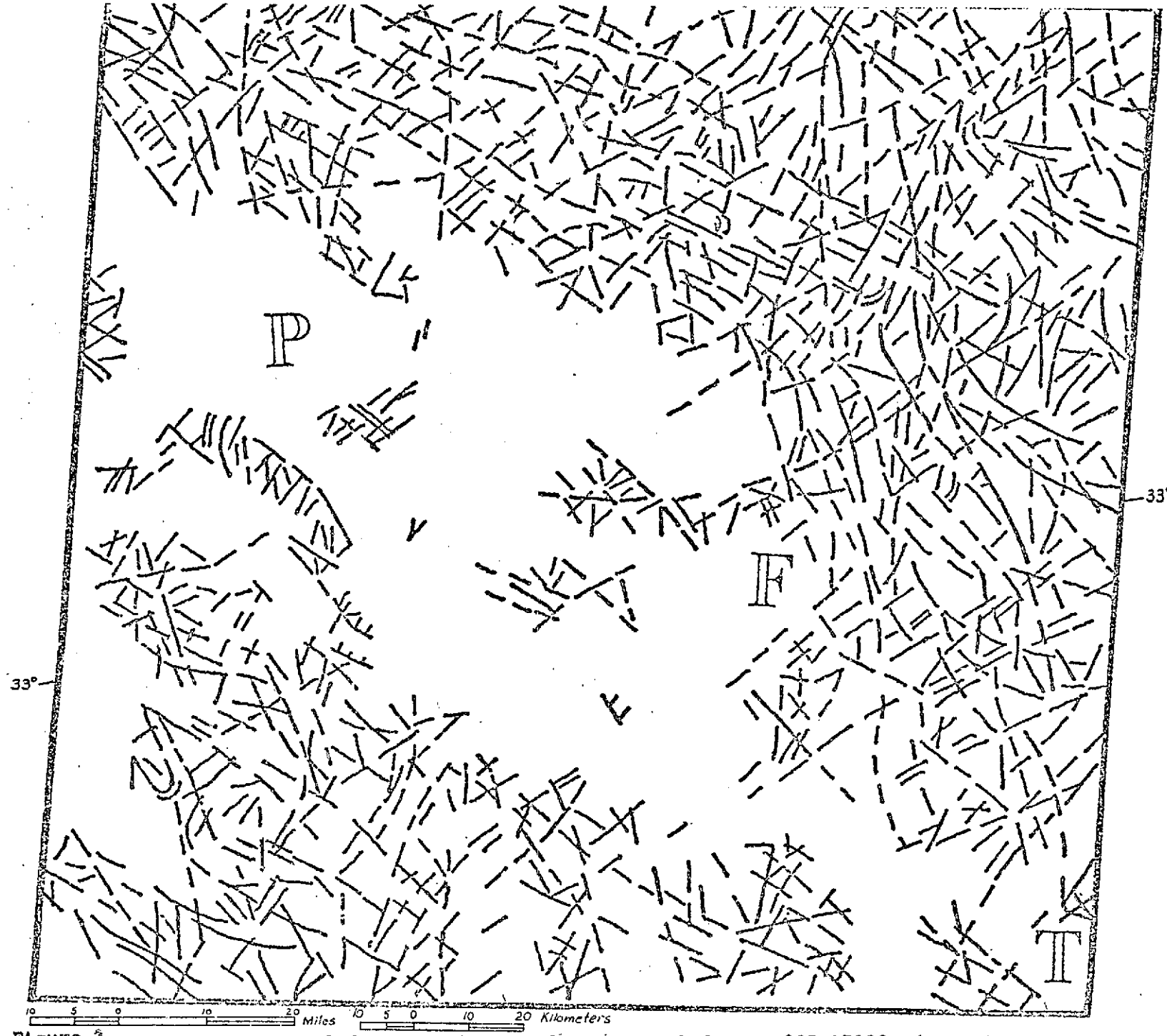


Figure 3. Linear structural features detectable on ERTS-1 frame 1085-17330. (Compiled by M. E. Cooley, 1973.) Capital letters indicate locations of Phoenix (P), Florence (F), and Tucson (T).

the modern erosion phenomena (arroyos, gullies, modern flood plains and terraces, and areas of sheet erosion and deposition), but also other features pertinent to the erosion problem, such as slope-local relief, landforms, rock units, soil particle size and erodibility, and classes of vegetative cover.

The P. I. also presented two talks at the 5-9 March Symposium on ERTS-1 Investigations at the Goddard Space Flight Center (see below for titles).

Category designation symbols: 1 D, 3 G, H, I, 7 F

f. Published articles: The following abstracts were published in the Abstract volume issued for the "Symposium on significant results obtained from ERTS-1," March 5-9, 1973, sponsored by NASA/Goddard Space Flight Center, Greenbelt, Maryland:

(1) "Application of ERTS-1 multispectral imagery to monitoring the present episode of accelerated erosion in southern Arizona", and
(2) "Assessment of flood damage in Arizona by means of ERTS-1 imagery."

g. Recommendations: None.

h. Changes in Standing Order Forms: None.

i. ERTS Image Descriptor Forms: N.A.

j. Data Request Forms submitted to GSFC NDPF, by date: None.

APPENDIX A

Evaluation forms for ERTS-1 images received by end of the reporting period, classified according to their coverage of standard USGS 1° x 2° quadrangles

Footnotes
(for evaluation forms)

[1](For cloud cover.) Percentage and distribution within the specified quadrangle are given.

[2]Contract, resolution, atmospheric degradation, and other defects are determined only for band 5.

[3]For contrast, any deficiencies at the lighter end of the gray scale are especially noted.

[4]Resolution generally is given only in general terms (low, moderate, or high).

[5]Atmospheric degradation includes the effects of haze, smog, and smoke.

[6]Other defects include electronic noise, partial frames, and photographic defects such as Newton rings and dirt.

ERTS-1 Study area (USGS 2°x1° quadrangle): AJO, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
07 Aug 1015-17440	NW corner	0%	fair	low	nil	none
23 Aug 1031-17325	E½ -	0%	poor	low	nil	none
24 Aug 1032-17382	N edge	0%	poor	low	nil	none
24 Aug 1032-17384	all but NE & SE corners	0%	poor	low	nil	none
25 Aug 1033-17441	W⅓	5%, spotty-cum. in NW corner	poor	low	nil	none
10 Sep 1049-17324	N½ E½	<5%, in NE center	poor	low	slight haze overall	none
10 Sep 1049-17331	S½ E½	trace	poor	low	mod. haze overall	none
10 Sep 1050-17383	N½ -	<5%, line of thin. cum. S of Gila R. valley	poor	low	slight haze overall	Newton rings
10 Sep 1050-17385	W¾ S½ -	<5%, cum. on W edge	poor	low	slight overall haze	
12 Sep 1051-17441	N¾ W¼	0%	poor	low	nil	none
28 Sep 1067-17324	N½E½ -	0%	fair	low -	Slight haze in SE¼ of coverage	none

ERTS-1 Study area (USGS 2°x1° quadrangle): AJO, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
26 Sep 1067-17330	S½ E½	0%	poor-fair	low	nil	Newton ring
29 Sep 1068-17382	N½	0%	fair	moderate	nil	none. Evaluation on band 6 (No band 5)
29 Sep 1068-17385	W¾ S½	0%	fair-good	moderate	nil	none
30 Sep 1069-17441	N¾ W¼	0%	fair-good	moderate	nil	none
30 Sep 1069-17443	SW corner	0%	fair	low-mod.	nil	none
16 Oct 1085-17330	N½ E½ -	0%	fair	moderate	nil	No band 5. Eval. on band 6
16 Oct 1085-17332	S½ E½	0%	fair	moderate	nil	No band 5. Eval. on band 7
03 Nov 1103-17332	N⅔ E½ -	0%	fair	moderate	nil	none
03 Nov 1103-17335	S½ E½ -	0%	fair	low-mod.	nil	none
04 Nov 1104-17391	W¾ N¾	0%	fair	low-mod.	nil	none
04 Nov 1104-17393	W¾ S⅓	0%	fair	low	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): AJO, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
05 Nov 1105-17445	W 1/6	0%	good	low-mod.	nil	none
21 Nov 1121-17333	N 2/3 E 1/2	0%	fair-good	mod.-high	nil	none
21 Nov 1121-17335	S 1/2 E 1/2	0%	good	mod.-high	nil	none
22 Nov 1122-17391	W 4/5 N 3/4	<5% Cumul. in SE corner of coverage	good	mod.-high	nil	none
22 Nov 1122-17394	W 3/4 S 1/3	20% Cumul. in SE 1/5 of coverage	good	moderate	nil	none
23 Nov 1123-17450	NW edge	0%	good	low-mod.	nil	none
27 Dec 1157-17332	E 1/2 N 2/3	100%				none
29 Dec 1159-17445	W 1/4 N 3/4	0%	good	moderate	nil	none
14 Jan 1175-17330	N 1/2 E 1/3	0%	fair	mod.-high	nil	none
14 Jan 1175-17333	S 1/2 E 1/2	0%	fair-good	moderate	nil	none
15 Jan 1176-17385	N 1/3	0%	good	high	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): AJO, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
15 Jan 1176-17391	S¾ W¾	0%	good	mod.-high	nil	none
01 Feb 1193-17333	N½ E½	0%	good	high	nil	none
01 Feb 1193-17335	S½ E½	0%	good	high	nil	none
02 Feb 1194-17391	W¾ N½	0%	fair-good	mod.-high	Possible slight haze in N½ W½ of quad.	none
02 Feb 1194-17394	S½ W½	0%	good	high	nil	none
03 Feb 1195-17450	N⅔ W¼	15% Cumul. in N¼ of coverage	good	moderate		none
03 Feb 1195-17452	SW corner	<5% Scatt. cumul. in SW corner of coverage	fair	moderate	nil	none
19 Feb 1211-17334	N½ E½	0%	fair-good	moderate	nil	none
19 Feb 1211-17341	S½ E½	0%	fair-good	moderate	nil	none
10 Mar 1230-17393	N½ W¾	<5% Scatt. cum. in NE corner	fair-good	moderate	nil	none
10 Mar 1230-17400	S½ W¾	tr. Spotty cum. in SW corner	good	moderate	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): MESA, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
22 Aug 1030-17265	E 3/5	trace cumulus in top center	fair	low - mod.	nil	none
22 Aug 1030-17271	SE edge	0%	poor-fair	low	nil	none
23 Aug 1031-17322	W 3/4 N 1/2	0%	fair	low-mod.	nil	none
23 Aug 1031-17325	W 2/3 S 1/2	0%	poor-fair	low	nil	none
09 Sep 1048-17270	E 3/5	5-10% in center and NE 1/4	fair	low	nil	none
10 Sep 1049-17322	W 3/4 N 1/4	trace	fair	low	nil	none
10 Sep 1049-17324	W 2/3 -	0%	poor	low	slight to mod. haze near Phoenix and ca. Roos. Lake	none
27 Sep 1066-17263	N 1/2 E 1/2 -	10%, mostly cum. cover in NW 1/4 of coverage	fair	low-mod.	nil	none
27 Sep 1066-17265	E 1/2 +	65%, thick cover streak-except in NE 1/4	fair	low-mod	nil	none
28 Sep 1067-17321	W 3/4 N 1/4	0%	fair-good	mod.-high	nil	none
28 Sep 1067-17324	W 3/4 -	0%	fair	mod.	slight haze or smog in W 1/4	none

ERTS-1 Study area (USGS 2°x1° quadrangle): MESA, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
15 Oct 1084-17271	E 3/5	5-10%, scatt. cum. in SE corner, N center	fair	mod.- high	nil	none
16 Oct 1085-17323	W 3/4 N 1/3	0%	fair-good	mod.- high	nil	none
16 Oct 1085-17330	W 3/4 -	0%	(fair-good)	(moderate)	slight haze-smog near Phoenix (W edge)	none Eval. on band 6
02 Nov 1102-17271	N 1/3 E 1/2 +	0%	fair	high	nil	none
02 Nov 1102-17274	E 3/5 -	0%	(good)	(high)	nil	Eval. on band 6
03 Nov 1103-17332	W 3/4 S 2/3	0%	fair-good	moderate	Slight haze at W edge	none
03 Nov 1103-17330	W 3/4 N 1/3	0%	fair	moderate	nil	none
20 Nov 1120-17274	E 3/5	30% cum. bands over entire coverage	poor-fair defic. in light end of gray scale	moderate	-	none
21 Nov. 1121-17330	E 3/4 N 1/4 +	0%	fair-good Slight defic. in light end	high	nil	none
21 Nov 1121-17333	S 5/6 W 3/4	0%	good	high		none
26 Dec 1156-17271	NE edge	0%	fair Slight defic. in light end	high	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): MESA, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
26 Dec 1156-17274	E 3/5	0%	fair-good Slight defic. in light end	high	nil	none
27 Dec 1157-17330	W 2/3 N 1/4	80-100% Thin cover in SE. Rest covered	—	—	—	none
27 Dec 1157-17332	W 2/3 -	80-100% Thin cover in center. Rest covered.				none
13 Jan 1174-17270	NE edge	0%	fair defic. in light end of gray scale	high	nil	none
13 Jan 1174-17272	E 1/2 +	0%	fair defic. in light end of gray scale	high	nil	none
14 Jan 1175-17324	N edge	0%	fair defic. in lightend of gray scale	high	nil	none
14 Jan 1175-17330	W 3/4	0%	fair-good	high	nil	none
01 Feb 1193-17330	N edge	0%	fair defic. in light end of gray scale.	high	nil	none
01 Feb 1193-17333	W 2/3 -	0%	fair-good	high	nil	none
18 Feb 1210-17273	NE edge	0%	fair-good	high	nil	none
18 Feb 1210-17280	E 3/5	0%	good	high	nil	none

ERTS-1 Study area (USGS 2° x 1° quadrangle): MESA, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
19 Feb 1211-17332	N edge	0%	fair-good	high	nil	none
19 Feb 1211-17334	W 2/3	0%	good	high	nil	none
26 Mar 1246-17281	E 2/3 -	trace along N edge; 2% along S edge	good	high	nil	none
27 Mar 1247-17335	W 3/5 -	60% Thick cumul. SW 1/3 clear	good	moderate	nil	none
15 Apr 1266-17393	W 1/5 -	0%	good	moderate	nil	none
13 Apr 1264-17281	E 2/3	0%	good	high	nil	none
14 Apr 1265-17335	W 3/5 -	0%	good	high	nil	none
02 May 1283-17332	W 3/5 -	0%	good	high	nil	none
20 May 1301-17333	W 1/2 +	0%				
01 May 1282-17280	E 3/4 -	70%				
19 May 1300-17275	E 2/3	15%				

ERTS-1 Study area (USGS 2° x1° quadrangle): NOGALES, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
21 Aug 1029-17213	NE corner	0%	fair	low	nil	none
22 Aug 1030-17271	N½	0%	fair	low-mod.	nil	none
22 Aug 1030-17274	S½	0%	fair-good	mod.	nil	none
08 Sep 1047-17214	E⅙	trace	fair	low-mod.	slight haze	none
09 Sep 1048-17272	all but W edge	15%, spotty cum. in W half; scatt. lines in E half	fair	low-mod.	nil	none
10 Sep 1049-17331	W½ -	<5%, scatt. cum. in NE¼ of coverage	poor	low	slight haze overall	none
26 Sep 1065-17213	E⅙	5%, spotty cum. in SE corner	fair	low	nil	none
27 Sep 1066-17272	E ¾	5%, spotty cum. S center, E half	fair	moderate	nil	none
28 Sep 1067-17330	W½	0%	fair	low-mod.	nil	none
15 Oct 1084-17274	all but NW edge	5%, thin streaks in W half; scatt. cum E¼.	fair	mod.-high	nil	none
16 Oct 1085-17332	W½ -	0%	(fair-good)	(moderate)	nil	Eval. on band 7

ERTS-1 Study area (USGS 2°x1° quadrangle): NOGALES, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
01 Nov 1101-17221	E 1/5	0%	(fair)	(moderate)	nil	Eval. on band 6
02 Nov 1102-17280	all but NW corner	0%	(good)	high	nil	none
03 Nov 1103-17335	W 1/2 -	0%	fair	moderate	nil	none
19 Nov 1119-17222	E 1/5	0%	fair	mod.-high	nil	none
20 Nov 1120-17281	all but NW corner	<5% Scattered cumul. in N 1/4	fair defic. in light end	high	nil	none
07 Dec 1137-17223	E 1/4	5% Thin band over NE corner of coverage	fair	moderate	-	Emulsion cracks over entire frame.
08 Dec 1138-17281	all but NW edge	60% Cumul. bands over W 3/5 of quad.	poor-fair defic. in light end of gray scale	low-mod.	-	Emulsion cracks over entire frame.
26 Dec 1156-17280	all but NW & SW edges	0%	fair-good Slight defic. in light end.	high	nil	none
12 Jan 1173-17220	E 1/5	0%	fair	low-mod.	nil	none
13 Jan 1174-17275	E 3/4	0%	fair-good	high	nil	none
14 Jan 1175-	W 1/2 -	0%	good	high	nil	none

ERTS-1 Study area (USGS 2° x1° quadrangle): NOGALES, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
01 Feb 1193-17335	W½ -	0%	good	high	nil	none
16 Feb 1210-17282	all but NW edge	0%	good	high	nil	none
17 Feb 1209-17224	E⅓	20% Cum along E edge, NE corner, W center	poor - fair	low	-	none
19 Feb 1211-17341	W½	60% Thin cum. except in SW corner and NW corner	poor - fair	low	-	none
07 Mar 1227-17224	E¼ -	15% Scatt. Cumul.	good	mod. - high	nil	none
25 Mar 1245-17225	E⅓	5% Scattered spotty cum. in E edge & W center	good	moderate	nil	none
26 Mar 1246-17283	all	0%	good	high	nil	none
27 Mar 1247-17342	W⅓ +	90% Bands of spotty cumul. NW corner clear	fair	moderate	-	none
12 Apr 1263-17225	E⅓	Trace over mtns.	good	moderate - high	nil	none
13 Apr 1264-17283	all	0%	good	high	nil	none
14 Apr 1265-16341	W⅔	0%	good	high	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): PHOENIX, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
07 Aug 1015-17440	W 2/5	0%	poor-fair	low	nil	none
23 Aug 1031-17322	NE1/4 E1/2	0%	poor	low	nil	none
23 Aug 1031-17325	S3/4 E1/3	0%	poor	low	nil	none
24 Aug 1032-17382	all	0%	poor	low	nil	none
25 Aug 1033-17435	W1/3 N1/2	0%	poor	low	nil	none
25 Aug 1033-17441	S2/3 W1/4	10% spot-cum. in SW corner	poor	low	nil	none
10 Sep 1049-17324	E1/3	<5% spotty cum. in NE corner	poor	low	mod. haze around Phoenix	none
11 Sep 1050-17380	N1/4	0%	poor	low	mod. haze overall	no band 5 Eval. on band 7
11 Sep 1050-17383	all but NE corner	5%, thin streaks in NE center of W1/2	poor	low	slight haze overall	Newton rings
12 Sep 1051-17434	W1/3 N1/3	0%	poor	low	nil	none
12 Sep 1051-17441	W1/3-	0%	poor	low	nil	none

ERTS-1 Study area (USGS 2° x1° quadrangle): PHOENIX, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
28 Sep 1067-17324	E¼	0%	fair	low-mod.	slight smog over Phoenix	none
29 Sep 1068-17380	N½	0%	fair	moderate	nil	none
29 Sep 1068-17382	all but NE corner	0%	fair	moderate	slight haze over Phoenix	none
30 Sep 1069-17434	W⅓ N¼	0%	fair-good	moderate	nil	none
30 Sep 1069-17441	W⅓ -	0%	fair-good	mod.- high	nil	none
16 Oct 1085-17330	E⅓	0%	(fair)	(moderate)	slight haze-smog over Phoenix	none Eval. on band 6
03 Nov 1103-17332	E⅓ -	0%	fair	low-mod.	slight haze over Phoenix	none
03 Nov 1103-17330	NE corner	0%	fair	low-mod.	slight overall haze	none
04 Nov 1104-17384	N⅓	0%	fair	low-mod.	nil	none
04 Nov 1104-17391	S¾	0%	fair	low-mod.	nil	none
05 Nov 1105-17443	W⅓ N⅓	0%	good	low-mod.	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): PHOENIX, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
05 Nov 1105-17445	S 3/4 W 1/4	0%	good	low-mod.	nil	none
21 Nov 1121-17330	NE corner	0%	fair defic. in light end of gray scale	high	nil	none
21 Nov 1121-17333	E 1/3	0%	good	high	nil	none
22 Nov 1122-17385	N 1/4	< 5% Thin streak cover in NW corner	fair	mod.-high	nil	none
22 Nov 1122-17391	all but NE edge	trace	good	moderate	nil	none
23 Nov 1123-17443	W 1/3 N 1/3	20% Spotty cumul. over NW 1/2	fair	low	—	none
23 Nov 1123-17450	S 3/4 W 1/4	5% Spotty cumul. in NW corner of coverage	fair-good	moderate	—	none
27 Dec 1157-17332	E 1/3	100%				none
29 Dec 1159-17442	W 2/3 N 1/4	0%	good	moderate	nil	none
29 Dec 1159-17445	W 1/3 -	0%	good	mod.-high	nil	none
14 Jan 1175-17330	E 1/4	0%	fair	mod.-high	nil	none

ERTS-1 Study area (USGS 2° x1° quadrangle): PHOENIX, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
15 Jan 1176-17385	all	0%	good	high	nil	none
01 Feb 1193-17333	E 1/3	0%	good	mod.-high	nil	none
02 Feb 1194-17385	N edge	0%	fair	mod.-high	nil	none
02 Feb 1194-17391	all but NE corner	0%	good	high	nil	none
03 Feb 1195-17450	W 1/3	100%				none
19 Feb 1211-17334	E 1/3	0%	fair-good	mod.-high	nil	none
10 Mar 1230-17391	N edge	100%	—	—	—	none
10 Mar 1230-17393	all	70% Thick cumin N 2/3 E 3/4	fair	moderate	-	none
27 Mar 1247-17335	E 1/2-	80% Partly clear in SE & SW corners	fair	low	-	none
28 Mar 1248-17394	all	70% Partly clear in center & SE edge	fair	low-moderate	—	none
29 Mar 1249-17400	W 1/3-	0%	good	moderate	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): SILVER CITY, NEW MEXICO-ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
21 Aug 1029-17211	N 1/4	trace in NE corner	fair	low	nil	none
21 Aug 1029-17213	all but NE edge	trace in NE 1/4	poor-fair	low-mod.	nil	none
22 Aug 1030-17265	N 1/4 W 2/3	0%	fair	low	nil	none
22 Aug 1030-17271	W 1/3	0%	fair	low-mod.	nil	none
08 Sep 1047-17211	N 1/2	35%, thick cover in W center w/ scatt. in E-cent.	poor-fair	low-mod.	nil	none
08 Sep 1047-17214	S 1/2	40%, cover in central and W-cen.	poor-fair	low-mod.	slight haze	none
09 Sep 1048-17270	N 3/4 W 1/3	70% - thick cover except along W edge	poor	low	nil	none
09 Sep 1048-17272	SW 1/4 W 1/2	50% thick cover in E half of coverage	poor	low	slight haze	none
26 Sep 1065-17211	N 1/2	trace (NE corner)	fair	low-mod.	nil	none
26 Sep 1065-17213	S 1/2	0%	fair	low-mod.	nil	none
27 Sep 1066-17265	N 2/3 W 1/3	80% thin streak cover, except in NE 1/4 of coverage	poor	low	slight haze in NE 1/4	none

ERTS-1 Study area (USGS 2°x1° quadrangle): SILVER CITY, NEW MEXICO-ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
27 Sep 1066-17272	W⅓ S½	25%, thin streak cover along W edge	poor-fair	low	–	none
14 Oct 1083-17213	N½ +	<5%, spotty cum. confined to NE corner	(fair-good)	(moderate)	nil	none Eval. on band 6
14 Oct 1083-17215	S½ –	0%	fair	mod.-high	nil	none
15 Oct 1084-17271	N⅔ W⅓	15%, scatt. cum.	fair	moderate	nil	none
15 Oct 1084-17274	SW¼ W½	20%, scatt. cum.	fair	moderate	nil	none
01 Nov 1101-17215	N ¾	0%	(fair-good)	(mod.-high)	nil	Eval. on band 6
01 Nov 1101-17221	S⅓	0%	(fair)	(moderate)	nil	Eval. on band 6
02 Nov 1102-17274	W⅓	0%	(good)	(high)	nil	Eval. on band 7
02 Nov 1102-17280	SW corner	0%	good	moderate	nil	None
19 Nov 1119-17220	N½ +	40%, band of spotty cum. over N central area	fair	moderate	–	none
19 Nov 1119-17222	S½ –	10-15% thin band over SW center	fair	low-mod.	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): SILVER CITY, NEW MEXICO-ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
20 Nov 1120-17274	N¾ W⅓	20% Cumul. bands in center & W⅓s of coverage	poor-fair defic. in light end of gray scale	moderate	–	none
20 Nov 1120-17281	SW¼ W½	25% Cumul. in N½ of coverage	fair Slight defic. in light end	low-mod.	–	none
07 Dec 1137-17220	N⅔	40% Band cover over NW⅔ of coverage	fair	med.-high	–	Emulsion cracks over entire frame
07 Dec 1137-17223	S⅓	40% Bands over W⅔ of coverage	fair	low	–	Emulsion cracks over entire frame
08 Dec 1138-17281	SW corner	5% Spotty cumul. on W edge	poor defic. in light end of gray scale	low	–	Emulsion cracks over entire frame.
26 Dec 1156-17274	N¾ W⅓	0%	good	high	nil	none
26 Dec 1156-17280	SW¼ W½	0%	good	high	nil	none
12 Jan 1173-17214	N¾	0%	fair-good	moderate	nil	none
12 Jan 1173-17220	S⅔	0%	fair-good	moderate	nil	none
13 Jan 1174-17272	E⅔ N¾	0%	fair Slight defic. in light end	mod.-high	nil	none
13 Jan 1174-17275	SW¼ W½	0%	fair-good	mod.-high	nil	none

ERTS-1 Study area (USGS 2° x1° quadrangle): SILVER CITY, NEW MEXICO-ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
18 Feb 1210-17280	N 2/3 W 1/3	0%	good	high	nil	none
18 Feb. 1210-17282	SW 1/4 W 1/2	0%	fair-good	moderate	nil	none
17 Feb 1209-17221	N 1/2	85% Thick cum. in all but W 1/3	poor	low	-	none
17 Feb 1209-17224	S 1/2	75% Thick cum. in all but W 1/4	poor	low	-	none
07 Mar 1227-17224	S 1/2	30% Thick cum. in W 1/3 of coverage	good	mod.-high	nil	none
25 Mar 1245-17222	N 1/2	trace over Pinaleno Mtns.	good	mod.-high	nil	none
25 Mar 1245-17225	S 1/2	trace over Pinaleno & Cabezas Mtns.	good	mod.-high	nil	none
26 Mar 1246-17281	N 2/3 W 1/4	0%	excellent	high	nil	none
26 Mar 1246-17283	SW corner	0%	good	moderate	nil	none
12 Apr 1263-17222	N 1/2-	5% Cumulon Edge of coverage	good	moderate-high	nil	none
12 Apr 1263-17225	S 1/2-	0%	good	moderate-high	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): TUCSON, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
22 Aug 1030-17271	E 3/4	0%	fair	low-mod.	nil	none
23 Aug 1031-17325	W 1/2 +	0%	poor	low	nil	none
09 Sep 1046-17270	E 3/4 N 1/2	<5%, scatt. cum. center & NE 1/4	fair	low-mod.	nil	none
09 Sep 1048-17272	E 3/4 S 1/2	<5% scatt. in E center, SE corn., SW	poor-fair	low	slight haze	none
10 Sep 1049-17324	N 2/3 W 3/5	0%	poor	low	slight haze overall	none
10 Sep 1049-17331	S 1/2 W 1/2 +	<5%, scatt. cum. in SW 1/4	poor	low	slight haze overall	none
27 Sep 1066-17265	E 2/3 N 1/2	100% streak cover	poor	low	-	none
27 Sep 1066-17272	E 3/4 S 1/2	100% thin streak cover	poor	low	-	none
28 Sep 1067-17324	W 2/3 N 2/3 -	0%	fair	low	nil	none
28 Sep 1067-17330	S 1/2 W 1/2 +	0%	poor-fair	low	nil	none
15 Oct 1084-17271	E 3/4 N 1/2	10%, scatt. in E half	fair	mod.-high	nil	none

ERTS-1 Study area (USGS 2°x1° quadrangle): TUCSON, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
15 Oct 1084-17274	E 3/4 S 1/2	20%, spotty cum. confined to S 1/2 E 1/2	fair	mod.	nil	none
16 Oct 1085-17330	W 3/5 N 2/3	0%	(fair)	(moderate)	nil	none Eval. on band 6
16 Oct 1085-17332	S 1/2 W 1/2	0%	(fair)	(moderate)	nil	Eval. on band 7
02 Nov 1102-17274	E 3/4 N 2/3	0%	(good)	(high)	nil	Eval. on band 7
02 Nov 1102-17280	E 3/4 S 1/3	0%	good	mod. - high	nil	none
03 Nov 1103-17332	W 3/5 N 4/5	0%	fair	low - mod.	nil	none
03 Nov 1103-17335	S 1/4 W 1/2	0%	fair	moderate	nil	none
20 Nov 1120-17274	E 3/4 N 2/3	25% Cumul. bands over E 1/2	poor-fair defic. in light end of gray scale	moderate	-	none
20 Nov 1120-17281	E 3/4 S 1/2	25% Cumul. bands over E 1/2	poor-fair defic. in light end of gray scale	low-mod.	-	none
21 Nov 1121-17333	W 3/5 N 3/4	0%	good	mod.-high	nil	none
21 Nov 1121-17335	S 1/3 W 1/2	0%	fair-good	moderate	nil	none

ERTS-1 Study area (USGS 2° x1° quadrangle): TUCSON, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
08 Dec 1138-17281	E¾ S⅓ +	80% Parts of SE corner clear.	poor-fair defic. in light end of gray scale.	low	-	Emulsion cracks over entire frame
26 Dec 1156-17274	N½ E¾	0%	good Slight defic. in light end.	high	nil	none
26 Dec 1156-17280	E¾ S½	0%	good	high	nil	none
27 Dec 1157-17332	W⅔ N⅔	100%				none
13 Jan 1174-17272	N½ E⅔	0%	fair-good Slight defic. in light end.	high	nil	none
13 Jan 1174-17275	E¾ S½	0%	fair-good	high	nil	none
14 Jan 1175-17330	N½ W¾	0%	good	mod.-high	nil	none
14 Jan 1175-17333	S½ W½	0%	fair-good	moderate	nil	none
01 Feb 1193-17333	N⅔ W⅗	0%	good	high	nil	none
01 Feb 1193-17335	S½ W½	0%	good	high	nil	none
18 Feb 1210-17280	N⅔ E⅔	0%	good	high	nil	none

ERTS-1 Study area (USGS 2° x1° quadrangle): TUCSON, ARIZONA

DATE AND FRAME NUMBER	COVERAGE	CLOUD COVER[1]	CONTRAST[2,3]	RESOLUTION[2,4]	ATMOSPHERIC DEGRADATION[2,5]	OTHER DEFECTS[2,6]
18 Feb 1210-17282	S½ E¾	0%	good	high	nil	none
19 Feb 1211-17334	N½ W½	0%	fair	moderate	nil	none
19 Feb 1211-17334	S½ W½	10% Thin cover in S ½	fair	low	slight haze over non-clouded area	none
07 Mar 1227-17224	SE edge	100% Cumul.				
25 Mar 1245-17225	3⅔ E⅕	20% Cum. thru center of coverage	good	moderate	nil	none
26 Mar 1246-17281	N½ E¾	5% Over Tortilla & Picacho Mtns	good	high	nil	none
26 Mar 1246-17283	E⅘ S½	0%	good	high	nil	none
27 Mar 1247-17335	N⅔ W½	20% Spotty cumul. in E¼	fair-good	moderate	nil	none
27 Mar 1247-17342	S½ W½ -	20% Spotty cumul. over E ⅓	fair	low-moderate	nil	none
12 Apr 1263-17222	NE corner	Trace over Pinalino Mtns	good	moderate-high	nil	none
12 Apr 1263-17225	S¾ E¼	0%	good	moderate-high	nil	none

APPENDIX B

The seven-phase interpretation program

This project is using a seven-phase program of interpretation of ERTS-1 data.

Phase 1 consists of preliminary mapping of the post-1890 erosion phenomena and other data relevant to the erosion problem (such as the more erodible soils) using only the ERTS-1 imagery.

Phase 2 consists of photointerpretive mapping of the modern erosion phenomena and other features relevant to the erosion problem from U-2 and RB-57 ultrahigh aerial photographs, in selected parts of the whole study area.

Phase 3 involves compilation of available published and unpublished ground-truth data (hydrologic, geomorphic, geologic, soil, etc.) on maps of suitable scales.

Phase 4 is a comparison of phase 1, 2, and 3 products, and additional photointerpretation, to prepare "enhanced information maps," noting any differences and anomalies.

Phase 5 consists of additional analysis made from repetitive ERTS-1 and ultrahigh airphoto coverage of the study area, noting any detectable erosional changes, such as widening, deepening, aggradation, or headward growth of gullies and arroyos, and also any added information (at least the differences in information content) on the features we are mapping resulting from time-variant phenomena such as changes in vegetation, soil moisture, and sun-elevation angle.

Phase 6 consists of appropriate field studies to obtain necessary supplemental ground-truth data, particularly to evaluate features found in earlier phases.

Phase 7 is the delineation of any new information detected on the ERTS-1 imagery and ultrahigh airphotos.